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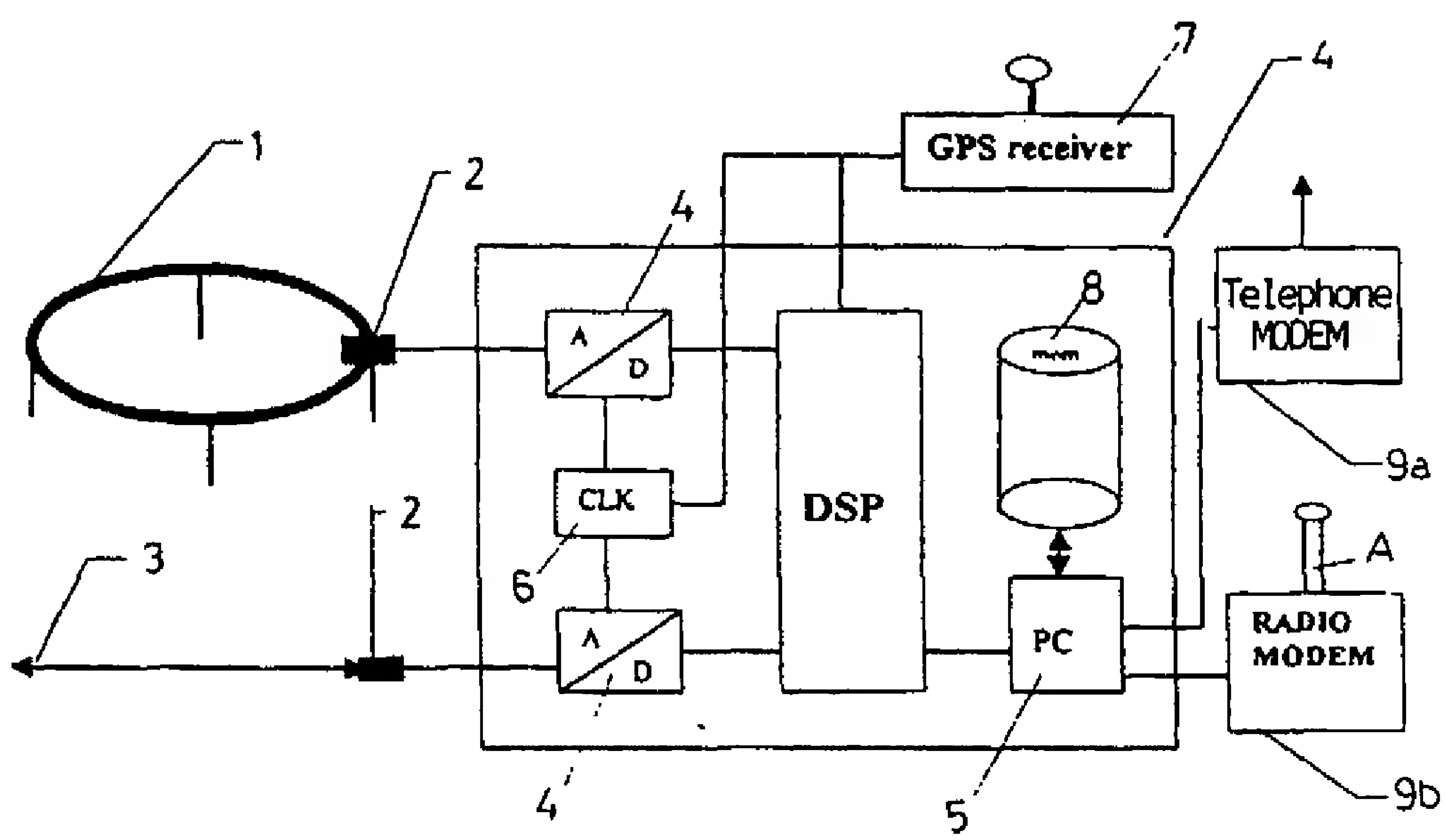
(54) **Title:** INSTALLATION FOR PREVENTIVE IDENTIFICATION OF EARTHQUAKE EPICENTRE AND DEPTH



(57) **Abstract:** The present invention relates to an installation for preventive identification of earthquakes, composed of multiple peripheral stations capable of detecting the very low frequency electromagnetic waves originated because of the mechanical deformation of underground layers of rocks and sending results to a central unit that processes received data in order to obtain the epicentre coordinates and depth of a future earthquake.

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Description

Installation for preventive identification of earthquake epicentre and depth.

The present patent application relates to an installation for preventive identification of earthquake epicentre and depth based on the detection and processing of the very low frequency (VLF) electromagnetic wave emissions which forewarn earthquakes.

The invention, of which no antecedents are known, is based on the fact that in earthquake zones the earth's crust is periodically subject to strong tensions and compressions that originate earthquakes when they reach the breaking point.

It is known that the geological structure of earthquake zones of the earth's crust is mainly composed of rocks with high contents of crystals. When subject to strong mechanical deformation, rocks produce electricity (piezoelectricity) with consequent generation of VLF electromagnetic waves, whose intensity and frequency are related to the mechanical tensions that originated them.

The frequencies of the electromagnetic waves range from fractions of Hertz to some tens of kilohertz; since the soil tends to attenuate higher frequencies, the deeper the phenomenon that originated the waves, the lower the received spectrum will be.

Being known that the intensity of electromagnetic emissions is proportional to the square of the forces applied by volume unit of the piezoelectric rock, an accurate statistical study of the territory will allow to predict the intensity of the future earthquake with good approximation.

It must be noted that the electromagnetic waves generated in the mechanically anomalous area attenuate with the square of the distance between the origin and reception point.

This means that the farther we get from the source, the weaker the

intensity of forewarning emissions will get and the same will be hidden by man-generated interference, static discharges and foreign radio waves.

The main purpose of the present invention is to predict the location of the earthquake epicentre and depth based on the analysis of forewarning VLF electromagnetic waves.

The earthquake epicentre is determined by using a network of peripheral receiving stations (minimum three) located on the territory at a distance of few hundreds of kilometres, possibly far away from interference sources, such as high voltage electric lines, towns and industrial centres.

Each peripheral station is composed of a series of suitable components (as illustrated with details in the description below) housed in a metal container.

Peripheral stations are programmed to automatically send results to a central unit over radio or telephone. The central unit makes a special innovative comparison (as described below) of the signals received from the peripheral stations in order to locate the epicentre of the future earthquake.

For major clarity the description of the invention continues with reference to the enclosed drawings, which are intended for purposes of illustration and not in a limiting sense, whereby:

- Fig. 1 is a diagrammatic view of a peripheral station used to detect VLF electromagnetic waves;

- Fig. 2 is a block diagram of the operating components of the peripheral station;

- Fig. 3 is a diagram that illustrates the method used by the central monitoring unit to process the information received from the peripheral stations in order to locate the earthquake epicentre;

- Fig. 4 is a three-dimensional view of a portion of the earth's crust with four peripheral stations according to the installation of the invention.

With reference to Figures 1 and 2, each peripheral station makes use of two receiving antennas: a main antenna (1) with balanced screened loop and a preferably underground service wire antenna (2).

The signals emitted from the two antennas (1, 2) are conveyed towards suitable devices housed in the container (C), after being adapted in impedance, amplified and filtered with suitable filters (3) in order to eliminate interference deriving from external interference sources.

Once inside the container, the signals detected by the antennas (1, 2) are converted from analogue into digital by means of suitable A/D devices (4).

The signals, now in digital format, are sent to a processing computer (5) after being marked with a clock signal (6) of one PPS (pulse per second) coming from a GPS satellite receiver (7) that supplies sample-time.

The computer (5) starts digital signal processing (DSP) in order to suppress the interference of the VLF electromagnetic waves through the comparison of the signals received by the two antennas (1, 2).

The signal obtained at the end of the digital signal processing (DSP) is memorised in a suitable memory (8) and conditioned for the subsequent transmission to a central monitoring and processing unit – not shown in the enclosed figures – over a telephone line connected to a modem (9a) or radio modem (9b) associated with a transmitting antenna (A) mounted on the roof of the container (C).

As soon as the attention level is exceeded by a peripheral station, the central monitoring and processing unit acquires the data from the stations via radio or telephone in real time and starts processing.

At this regard, the central unit is equipped with a first computer used to acquire and memorise the signals coming from the stations located on the monitored territory, and a second computer used for DSP (Digital Signal Processing) operations in order to process the signals received from the peripheral stations.

The operating logic of the second computer is diagrammatically illustrated in Figure 3, which shows the processing of signals coming from four peripheral stations (Rx-A, Rx-B, Rx-C, and Rx-D).

More precisely, the operation consists in processing the signals

coming from the peripheral stations, after suitable equalisation, to find the correlation peak (the correlation consists in the temporal flow of the signals received from the peripheral stations in numerical mode until they coincide within a predefined time period).

The correlation peak is used for the temporal alignment of the signals received from the peripheral stations in order to measure the relative delays [t(a-b), t(a-c), t(a-d)] between the time marks of the signals received from the stations located in the territory.

In other words, the VLF signals received from the stations are marked with a time signal derived from a GPS, and time differences of arrival are calculated in the data collection and processing centre with the correlation and GPS marking technique, as shown in Figure 3.

Delays are measured on several signal samples received from each station. The results are then averaged and data is acquired when minimum variance is achieved.

Now, by knowing the station coordinates and the signal time difference of arrival, the epicentre coordinates and the earthquake depth can be obtained by using the TDOA (Time Difference Of Arrival) technique.

This technique allows for the 2-D identification (x-y) of the earthquake epicentre with three stations. In addition to higher accuracy, the use of four or more stations allows for the possibility of 3-D operation, which includes the z axis representing the epicentre depth.

With reference to a Cartesian system (x, y, z) as shown in Fig. 4, the unknown coordinates of the emission signal are obtained by solving the system:

$$\begin{cases} \sqrt{(x-x_b)^2+(y-y_b)^2+(z-z_b)^2}-\sqrt{(x-x_a)^2+(y-y_a)^2+(z-z_a)^2}=c\cdot t_{ab} \\ \sqrt{(x-x_c)^2+(y-y_c)^2+(z-z_c)^2}-\sqrt{(x-x_a)^2+(y-y_a)^2+(z-z_a)^2}=c\cdot t_{ac} \\ \sqrt{(x-x_d)^2+(y-y_d)^2+(z-z_d)^2}-\sqrt{(x-x_a)^2+(y-y_a)^2+(z-z_a)^2}=c\cdot t_{ad} \end{cases}$$

where t(ab), t(ac), t(ad) are the delays of the signals received from stations B, C and D, respectively, with respect to the signal received from station A and constant C is the propagation speed of electromagnetic waves underground.

Therefore, the Cartesian system can be used to identify the epicentre coordinates (x, y), as well as its depth (z).

In case of three peripheral stations, the processing procedure should consider the delays of the signals from two stations with respect to the signals from the third station, and the calculation system should be composed of only two equations with two unknowns, that is to say the epicentre co-ordinates (x, y).

Claims

1) Installation for preventive identification of earthquakes, characterised in that it is composed of multiple peripheral stations capable of detecting the very low frequency (VLF) electromagnetic waves originated because of the mechanical deformation of the underground layers of rocks and sending results to a central processing unit; it being provided that each peripheral station is composed of two receiving antennas: a main antenna with balanced screened loop (1) and a preferably underground service wire antenna (2), whose signals, after being adapted in impedance, amplified and filtered, are converted from analogue to digital by means of suitable A/D devices (4), and then sent to a processing computer (5) after being marked with a clock signal (6) of one PPS (pulse per second) coming from a GPS satellite receiver (7) that gives the sample-time; it being provided that the computer (5) starts digital signal processing (DSP) for the suppression of interference in VLF electromagnetic waves thanks to the comparison of the signals received from the two antennas (1, 2), so that the processed signal can be memorised in a memory (8) and sent to the central processing unit via telephone or radio as soon as the attention level of the peripheral station is exceeded; it being provided that the central processing unit is equipped with a first computer used to acquire and memorise the signals (Rx-A, Rx-B, Rx-C, Rx-D.......Rx-*n*) coming from the stations located in the monitored territory, and a second computer used to process the signals, after equalisation, to find the correlation peak according to the method illustrated in the description above, which allows for the temporal alignment of the signals in order to measure the relative delays [t(a-b), t(a-c), t(a-d)....t(a-*n*)] between the time marks of the signals received from the peripheral stations; it being provided that the central processing unit is capable of measuring the delays on multiple signal samples received from each peripheral station and averaging the results so that data is acquired and used when minimum variance is achieved, knowing the station coordinates and the signal time differences of arrival, in order to

obtain the epicentre co-ordinates and the depth of the future earthquake, based on the processing technique known as TDOA (Time Difference Of Arrival) and on the calculation modes illustrated in the description above.

Fig.1

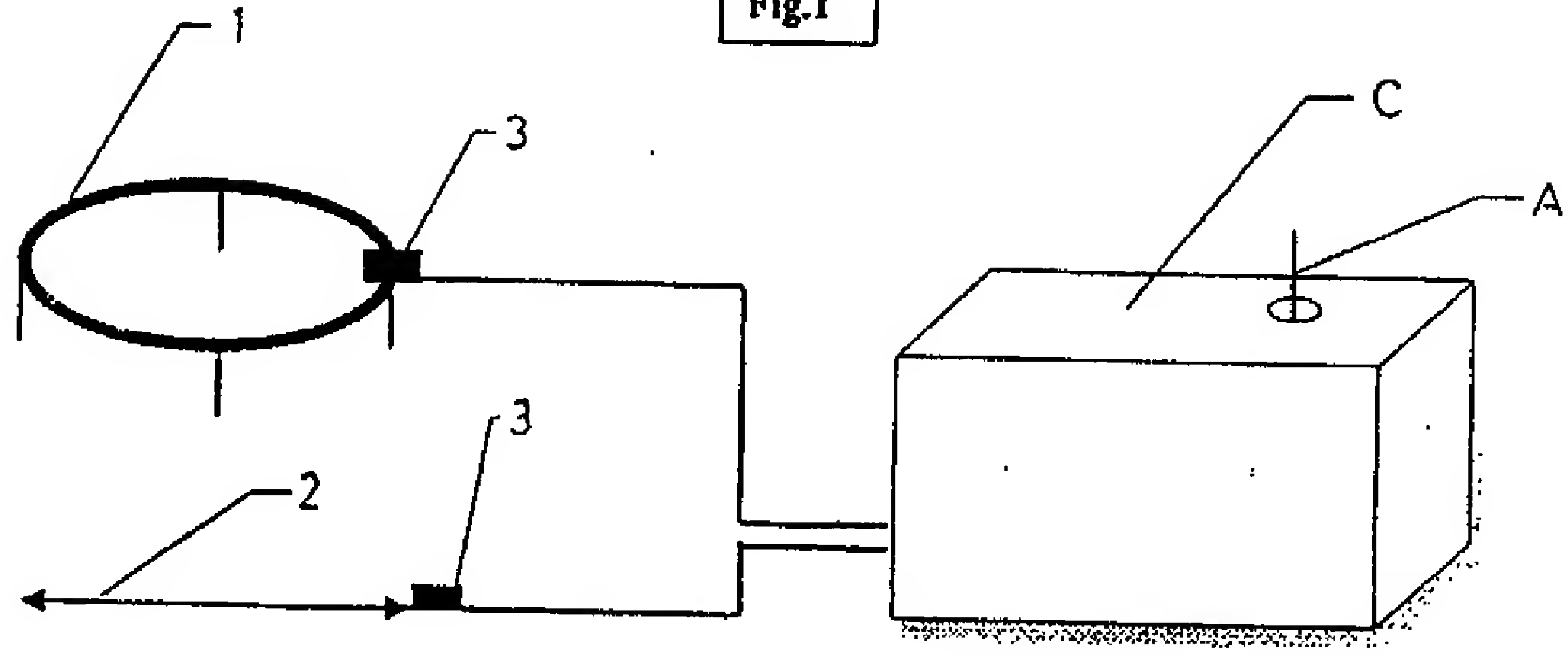

1
3
C
A
3
2

Fig.2

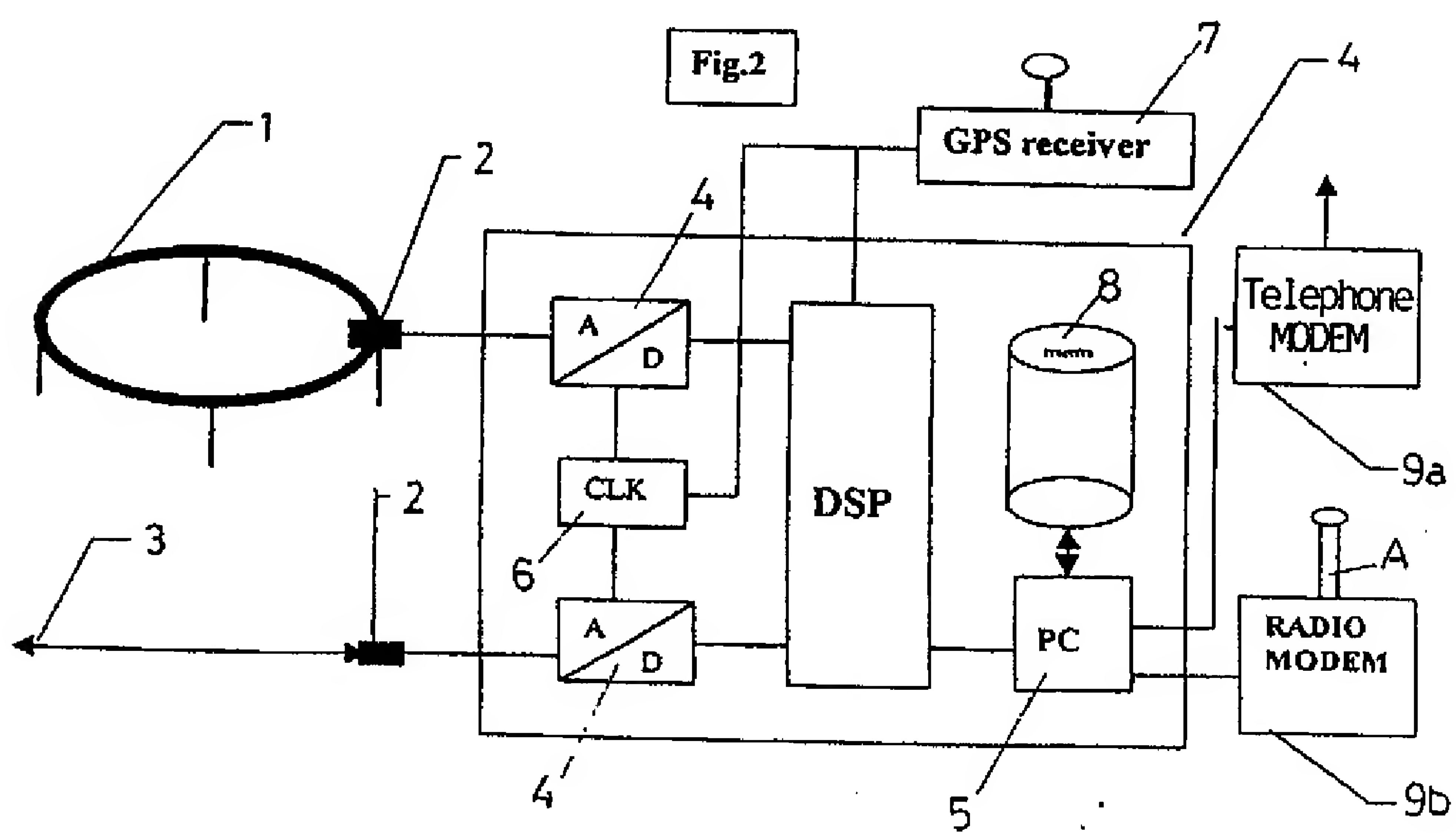

7
4
GPS receiver
1
2
4
8
Telephone MODEM
A D
CLK
DSP
9a
2
3
6
A
A D
PC
RADIO MODEM
4'
5
9b

Fig. 3

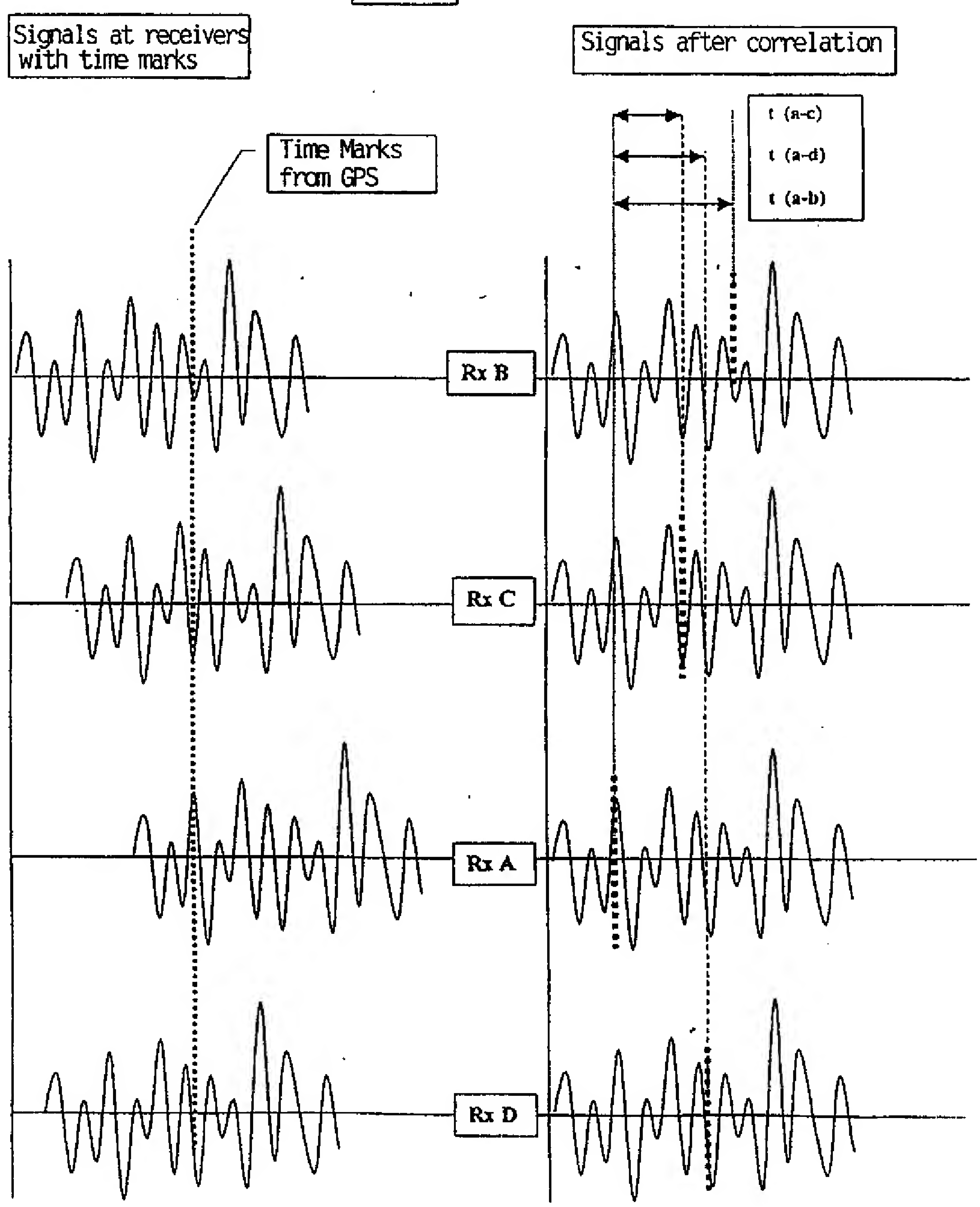
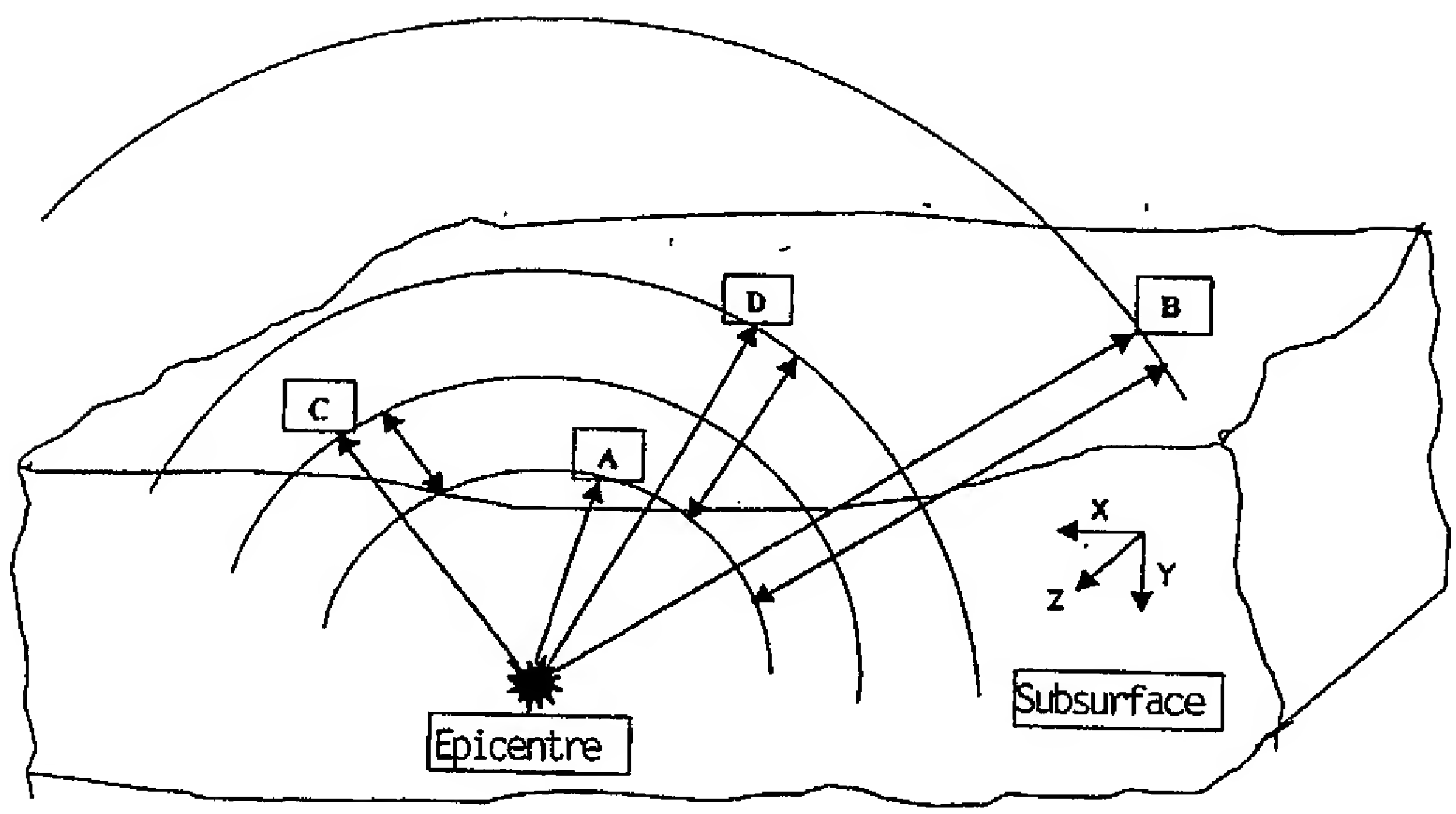

Signals at receivers with time marks
Signals after correlation
t (a-c)
t (a-d)
t (a-b)
Time Marks from GPS
Rx B
Rx C
Rx A
Rx D

Fig 4



INTERNATIONAL SEARCH REPORT

International Application No
PCT/IT 02/00512

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01V1/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01V

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data, INSPEC, IBM-TDB

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5 694 129 A (FUJINAWA YUKIO ET AL) 2 December 1997 (1997-12-02) abstract figures 1-3,7,9 column 2, line 11 -column 3, line 37 column 8, line 35 -column 9, line 57	1
A	US 4 837 582 A (TAKAHASHI KOZO ET AL) 6 June 1989 (1989-06-06) abstract figures 2,3 column 2, line 42 - line 59	1
A	US 4 904 943 A (TAKAHASHI KOZO) 27 February 1990 (1990-02-27)	

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
9 December 2002	18/12/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	de Heering, Ph.

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5 811 974 A (HATA MASAYASU) 22 September 1998 (1998-09-22) abstract figures 6-8 column 6, line 27 - line 43 -----	1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/IT 02/00512

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			JP	1813607	C	18-01-1994
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